

Einstein's Gravity

Suggested Grade Level(s): 11 or 12 Physics Class

Estimated class time: 3 to 5 days depending on whether the curved space model is done as a demonstration and how much time is spent in research.

Summary

Students will read the 1919 edition of the Cosmic Times and respond by raising questions to be answered with further research. They will make a model of curved space to view the motion of spheres as explained by General Relativity. After presentations of their research to the class they will create an interview with Albert Einstein.

Objectives

- Students will be able to compare and contrast two different models that explain the gravitational force.
- Students will be able to explain what is meant by gravity as curvature in space and time.
- Students will be able to answer questions that are raised about Albert Einstein, his life, the times and his theory of general relativity.
- Students will make a model of curved space.
- Students will begin an exploration of the scientific process and how new ideas and technology change our understanding of the world around us and raise new questions to be answered.

National Standards

National Science Standards

- NS.9-12.1 SCIENCE AS INQUIRY
As a result of activities in grades 9-12, all students should develop
 - Abilities necessary to do scientific inquiry
 - Understandings about scientific inquiry
- NS.9-12.2 PHYSICAL SCIENCE
As a result of their activities in grades 9-12, all students should develop an understanding of
 - Motions and forces
 - Interactions of energy and matter
- NS.9-12.4 EARTH AND SPACE SCIENCE
As a result of their activities in grades 9-12, all students should develop an understanding of
 - Origin and evolution of the earth system

- **NS.9-12.7 HISTORY AND NATURE OF SCIENCE**

As a result of activities in grades 9-12, all students should develop understanding of

- Science as a human endeavor
- Nature of scientific knowledge
- Historical perspectives

National Language Arts Standards

(From the National Council of Teachers of English)

- **NL-ENG.K-12.7 EVALUATING DATA**

Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and non-print texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.

- **NL-ENG.K-12.8 DEVELOPING RESEARCH SKILLS**

Students use a variety of technological and information resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Knowledge Prerequisite

Students should be familiar with Newton's Law of Universal Gravitation.

Teacher Background/Notes

Teachers' Domain (<http://www.teachersdomain.org/>)

Teacher's Domain is a free website offered through WGBH (public TV) in Boston. You must register with the site, but registration is free. See the end of the lesson for more on the Teachers' Domain website. Once registered, you will find the video clip demonstration of Curved Space by following the following submenus:

Physical Science

↳ Fundamental Theory

↳ Cosmology and Gravity

↳ Relativity and The Cosmos

↳ View

↳ Animations in box at right

↳ Space Animation

Materials

- Teacher's Domain (see note above)
- Saran Wrap (NOT generic plastic wrap)
- Support for plastic wrap – Two interlocking 12 inch embroidery hoops, round trash can and tie, lids from Deli platters, etc.
- Assorted sizes of spheres to roll
- Black Sharpie permanent marker

Procedure:

I. Engagement

1. Read the lead article from the Cosmic Times

- Imagine you are living in 1919.
- Would you know who Albert Einstein was?
- Do you know what a solar eclipse is and/or have you ever seen one?
- What does curved space mean to you? How does it relate to gravity?

At the end of this unit you will be able to answer these questions and some more within the context of an interview with Albert Einstein.

2. Show the video clip of the sun warping space-time from Teacher's Domain.

- a. How did Isaac Newton explain gravitation?
- b. How does this explain that a beam of light, which is massless, bends with gravity's force?

Teachers: This is a connection to prior knowledge, but should also allow students to start a list of questions that they will answer later in the lesson.

Answers:

- a. *Newton explained gravitation as the interaction of two masses creating an attractive force.*
- b. *This does not explain the observed bending of light, which has no mass.*

3. Think / Pair / Share ideas

***Teachers:** You may want to create a list of the ideas shared for students to use when they try to decide what they wish to research further. Some classes may appreciate the guidance from this early point. The term ideas is used here because the students may raise new questions or come up with ideas that are not direct answers to the two questions being asked. This is the jumping off point for the research step and is encouraged.*

Think – about the Cosmic Times, the questions in #3 and the video clip. (The first is based on prior knowledge; the second will be a bit tougher, perhaps.)

Pair – students share their answers to the questions with a single partner. Share any new questions and ideas you may have.

Share – invite partners to share ideas with the full class. You may solicit new questions and ideas as well as the two answers. Make a list of the answers and ideas

II. Exploration

In Groups:

Students should make their own model of curved space.

Equipment – Interlocking embroidery hoops – one per group; Metal spheres of various sizes for each group; Saran[®] Wrap (generic NOT suggested) one roll in classroom.

***Teachers:** For students to make the model, Lycra or spandex does very nicely and can be reused year after year. If the teacher is demonstrating the model, the Saran Wrap will allow the spheres to be visible on the overhead projector. Do not try to reuse the Saran Wrap. Use a Sharpie pen to draw grid lines on the Saran Wrap to see the curving of the x and y directions.*

1. Stretch a piece of Saran[®] Wrap taut between the two hoops.
2. Tighten the hoops.
3. Place the hoop on a table with the Saran[®] Wrap up and hoop down. This will elevate the hoop off the table by about an inch. Further elevation will enhance the effect. A larger demonstration can be made with a cheesecake pan, a three-foot wide trash can, the lid to a deli platter with the top cut out so only the side remains. If you choose one of these larger demonstrations, secure the Saran Wrap securely to the sides. Commercial Saran Wrap is wider than the standard kitchen roll.
4. Place the larger of 2 metal spheres in the middle of the Saran Wrap.
5. Roll a smaller sphere across the Saran[®] Wrap at some distance between the center of the hoop with the larger sphere and the hoop itself.
6. Students may experiment by changing the relative sizes of the two spheres, the speed of the rolling sphere, the starting position, etc. to get a nice “orbit”.

Teacher: This also makes a good demonstration on an overhead projector if you do not have the materials or time to have groups explore this on their own. The hoop can be placed on an overhead projector supported by two pieces of wood about an inch high to elevate it.)

Upon completion of the activity, students will answer the following questions:

- a. What path does the moving sphere follow?
- b. What happens when you start the moving sphere at a faster speed?
- c. Sketch what you think would happen if there were no friction.
- d. Compare this to the orbit of a planet.

Answers:

- a. The moving sphere follows a curved path around the center sphere.*
- b. If the moving sphere starts too fast, it will not appear to curve and may jump the edge of the hoop. If it starts too slow, it will roll right into the center sphere.*
- c. They should have a full loop around the sphere or a path curving across the surface.*
- d. The orbit of a planet is an ellipse because of the central force of gravity. It looks like the path of the sphere on the hoop.*

III. Explanation

Students **in their groups** will create 3 questions that they would like to research in depth. The groups will create a master list of questions about Einstein and/or his theory of gravity.

Teachers:

- Differentiated instruction: for some groups biographical questions might be easier to answer than scientific questions*
- Use the list of ideas from the Engagement or the list of questions in the appendices to provide guidance to students who may be “stuck” at this point.*

With teacher approval, each group will research on the Internet to answer one of their questions and make a presentation for their classmates. Presentations may be Power Point or posters with an oral component that involves **all** group members.

IV. Extension

- Students may wish to expand on the information presented or answer new questions that were raised in their classmates’ presentations.
- Students may also create a crossword puzzle using new vocabulary that has rows and or columns that resemble curved space.

- Students may view the Elevator Animation from the Teacher's Domain website or take an elevator ride with a spring scale and a kilogram to see firsthand how the apparent weight changes.
- Students may read the Alan Lightman article, *Relativity and the Cosmos*, from Teacher's Domain.

V. Evaluation

Each student will create an interview with Albert Einstein for next week's Cosmic Times. Ask him 5 questions and provide the answers that he would have given you. You may write a script or tape the interview.

Teachers: Oral presentations of the script will be optional and depend on the time frame of the lesson on the whole.

More on the Teachers' Domain

From their website (<http://www.teachersdomain.org/>):

Teachers' Domain is an online educational service with two related components — collections and courses — that help teachers enhance their students' learning experiences and advance their own teaching skills. The Teachers' Domain collections include classroom-ready multimedia resources for use in lessons or independent study, and the Teachers' Domain Professional Development courses utilize many of the same resources along with videos of exemplary classroom practice.

The collections provide learning experiences that no textbook can. This ever-expanding library currently includes collections on:

Science: Life Science, Physical Science, Engineering, Earth and Space Science

Social Studies: The Civil Rights Movement, *Brown v. Board of Education*

Teachers' Domain offers:

- High-quality multimedia from *NOVA*, *American Experience*, and other public television productions and partners
- Video and audio clips, interactives, images, and documents
- Explanatory background articles for each resource
- Correlations to state and national curriculum standards
- Media-rich lesson plans
- Resource management tools
- The Resource management tools allow you to organize the clips that are useful in your personal folders.